Spring 6-12-2013

Sustainability issues regarding bamboo as a renewable feedstock for fuels and materials

Claudia Daza
ECN

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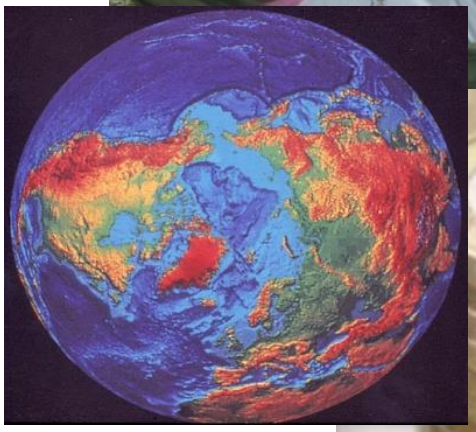
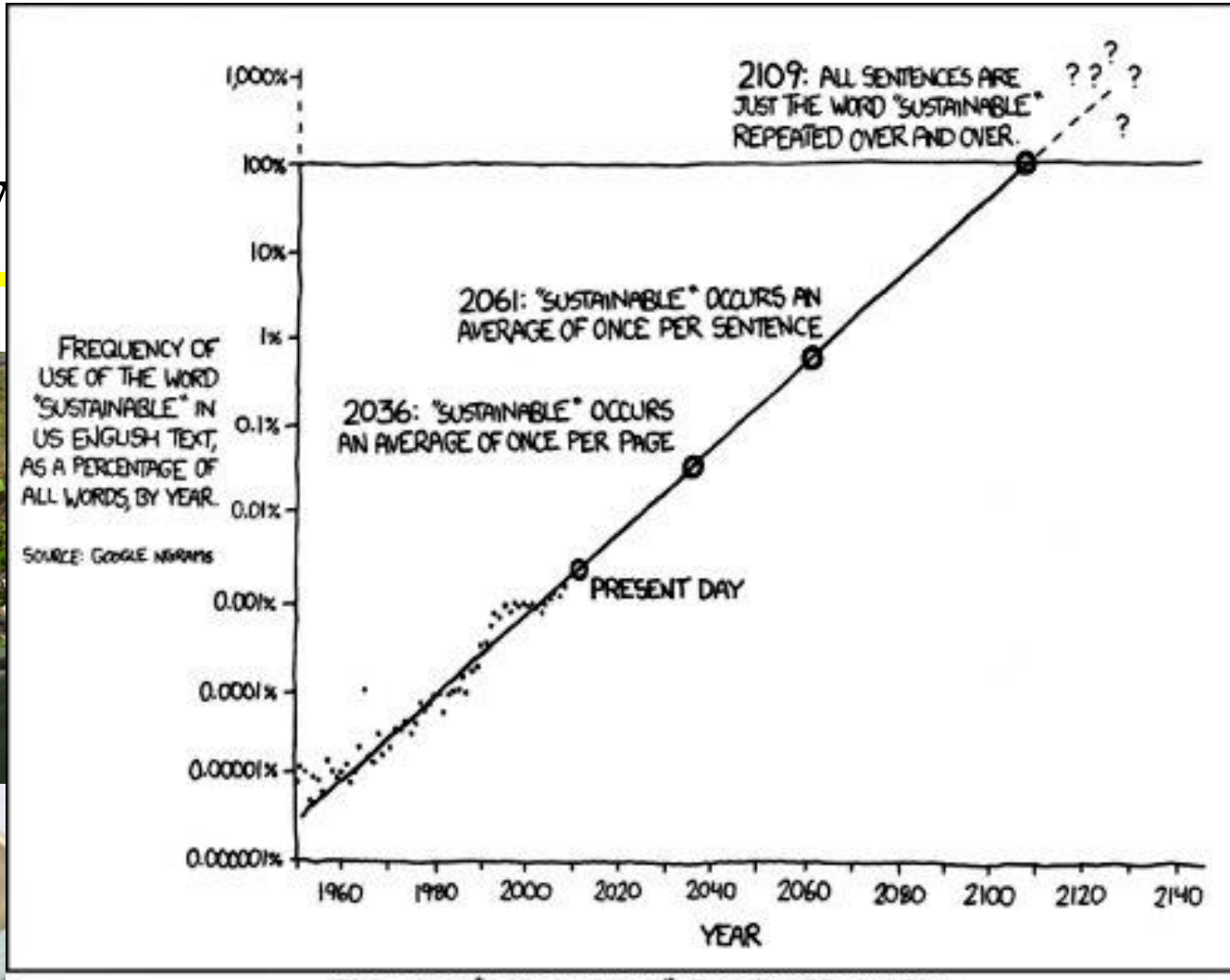
Claudia Daza M.

BioEnergy IV – Otranto – Italy

June 12- 2013

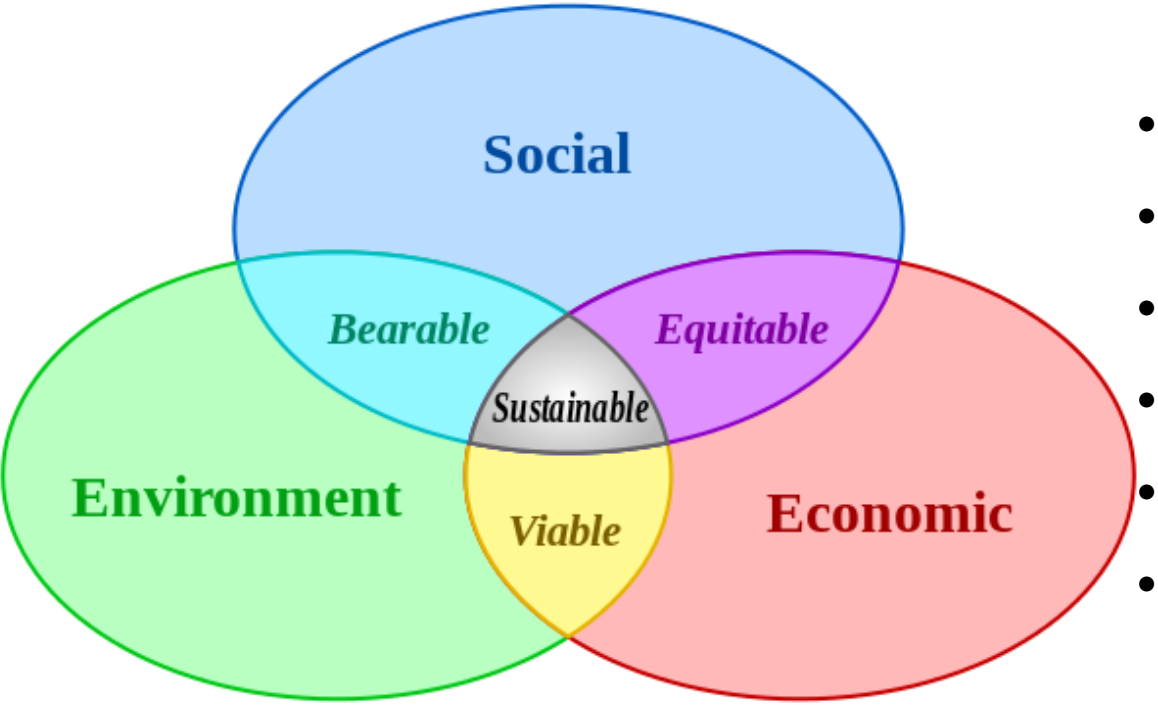
Sustainability





THE WORD "SUSTAINABLE" IS UNSUSTAINABLE.

Sustainable Biomass



Sustainability Themes

- **Greenhouse gas emissions**
- Competition with food and local applications
- Biodiversity
- **Environment**
- Prosperity
- Social well-being.

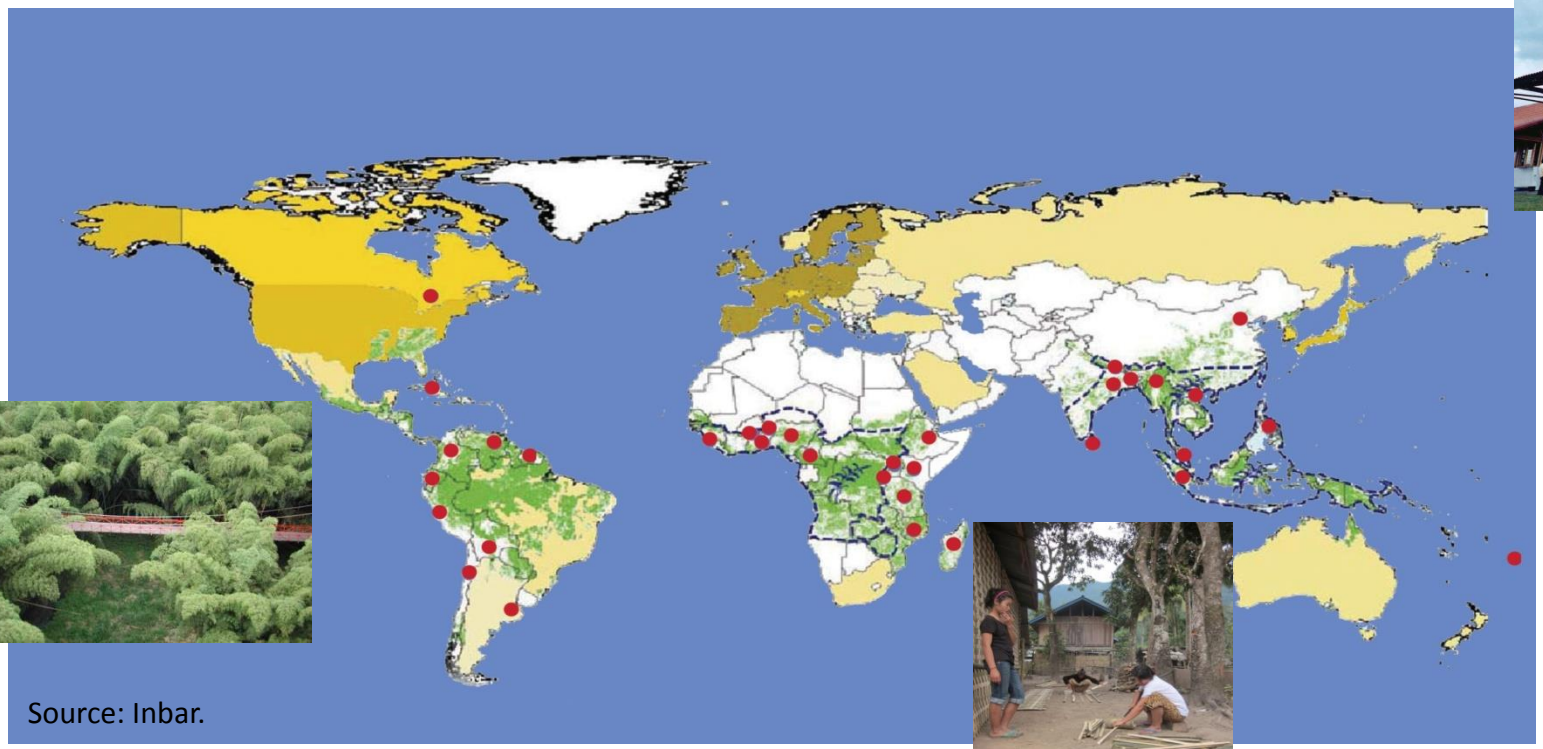
Criteria➔Indicators

Bamboo:

An alternative sustainable feedstock for the biobased economy

Why bamboo?

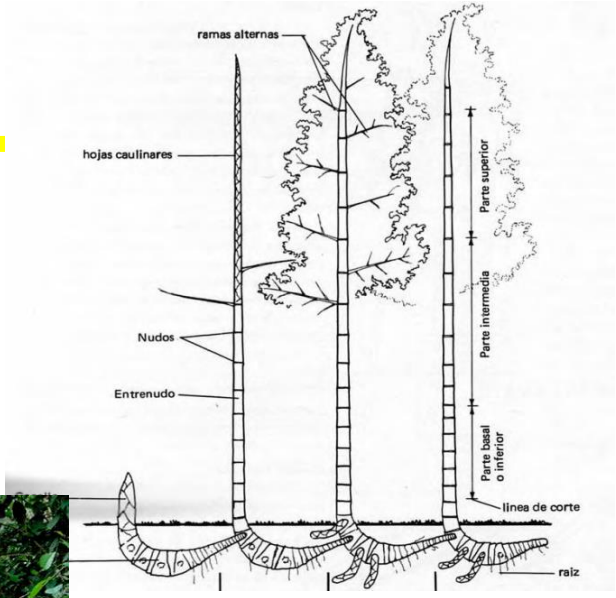
- ±36 Million Hectares
- Millions of tons could be harvested sustainably each year
- Opportunities for sustainable development



Source: Inbar.

Why bamboo?

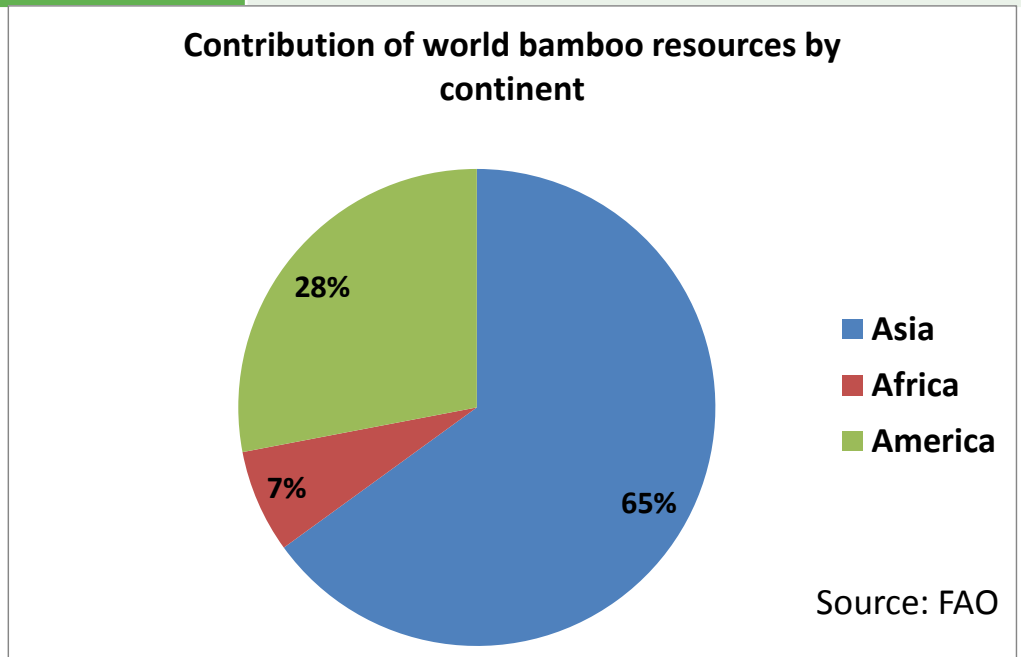
- Fast growing
  - 10-40 Ton/Ha-year
- **Regenerates itself** after it has been responsibly cared for and harvested➔ **No replanting**
- Excellent reforesting crop
  - Low consumption of fertilizers ➔(GHG)
  - Easy propagation➔**no seeds**
  - Water table preservation
  - Biodiversity preservation
- CO_2 sump
- Opportunities for rural development
  - Product diversification



Current Uses

Major global supplier of products: China

Plant section	Current use
Culm	Finished products: housing, flooring furniture, paper, charcoal.
Leaves	Left in the field as fertilizer, and/or collected for animal feed.
Branches	Low value applications, low market (chopsticks)
Roots	Food



BAMBUSA VULGARIS VAR. VULGARIS SCHRADER EX WENDLAND

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SOCIEDAD COLOMBIANA DEL BAMBU

Lignocellulosic feedstock

Logistics Cost

Feedstock		Bamboo culm	Cane Bagasse	Wheat straw	Wood
HHV (dry)	MJ/kg	17-20	18-20	16-19	17-20
Density	kg/m^3	**500-700**	150-200	160-300	200-500
Yield	Ton/Ha-year	**20-40**	7-10	6-12	10-20
Overall composition (dwt %)					
Cellulose		40-60	35	38	50
Hemicellulose		20-30	25	36	23
Lignin		20-40	20	16	22
Others**		2-10	20	10	5

** Ash, resins, etc.

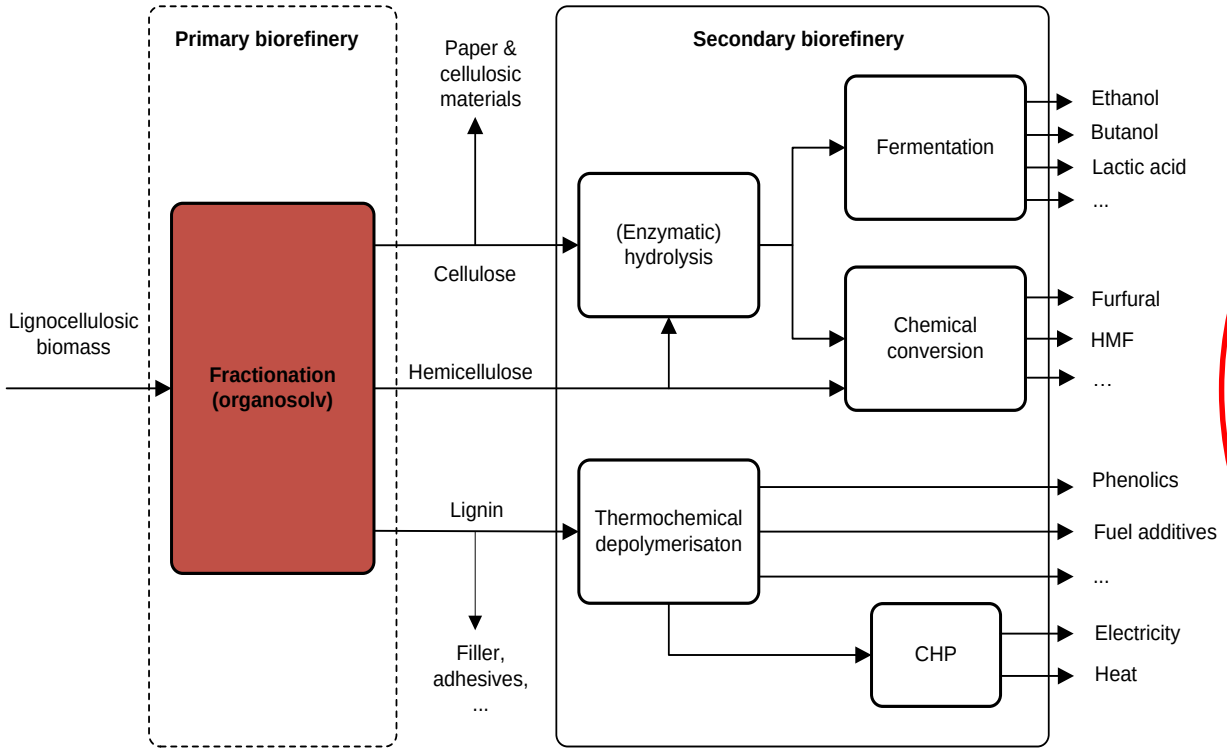
Yields and composition depend on:

specie and age of the plant, plant section,

cultivation site and harvesting season.

Biobased: Chemicals+ Materials+ Energy

Lignocellulosic Biorefinery



Fibers
Fertilizer
Biochar

Solid Fuel in Power Plants

Coal & biomass

Bamboo Project: Jan 2011-April 2013

Torrefied Pellets for
Sustainable Biomass Export from Colombia

Assessing the whole chain of bamboo cultivation & collection via torrefaction upgrading to application as biofuel

NL Agency
Ministry of Economic Affairs

Bamboo as a biomass import chain

Assessment of:

- technical suitability
- sustainability
- economical feasibility

for:

- Co-firing torrefied Colombian bamboo pellets in NL

NL Agency
Ministry of Economic Affairs

The SBI scheme aims to give an impulse to the promotion of the sustainability of the biomass import chains for **biobased energy and chemical applications/transport/electricity/heating and chemicals/materials**

Looking for certification

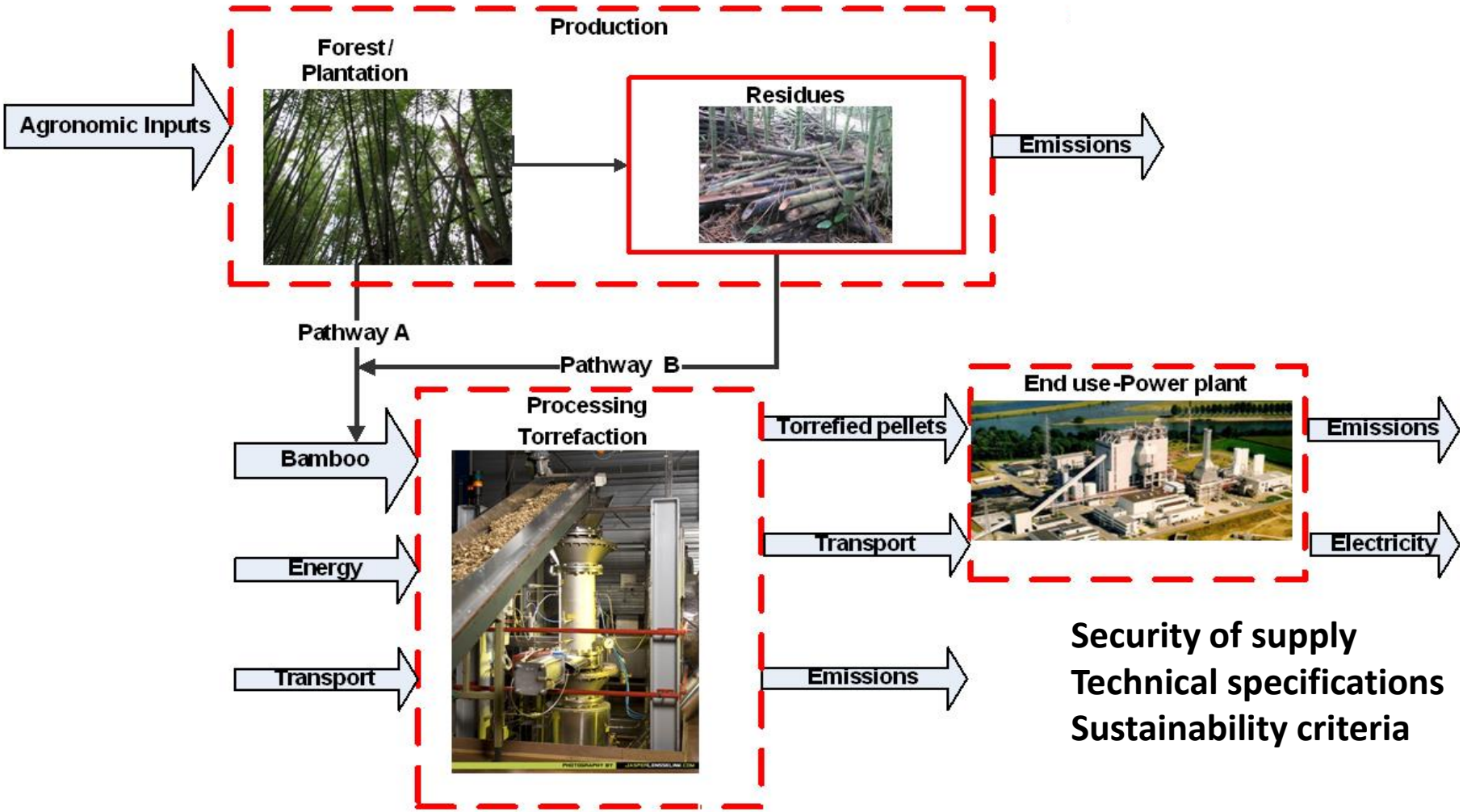
The Dutch technical agreement (NTA8080) describes the requirements for **sustainably produced** biomass for energy applications (power, heat & cold and transportation fuels).

Biomass includes solid as well as liquid and gaseous biofuels. The NTA 8080 is intended to be applied at organizations that wish to sustainably:

- **Produce,**
- **Convert,**
- **Trade; or**
- **Use biomass for energy generation or as transporting fuel.**

  - **Currently being revised and extended to bio-based products**

Biomass chain assessment



Torrefaction for upgrading biomass

- Process parameters
  - Temperature: 200-300 °C
  - Absence of oxygen

Tenacious and fibrous
LHV = 9 - 12 MJ/kg
Hydrophilic
Biodegradable
Heterogeneous

Torrefaction

Friable and less fibrous
LHV = 18 - 24 MJ/kg
Hydrophobic
Preserved
Homogeneous

Pelletisation

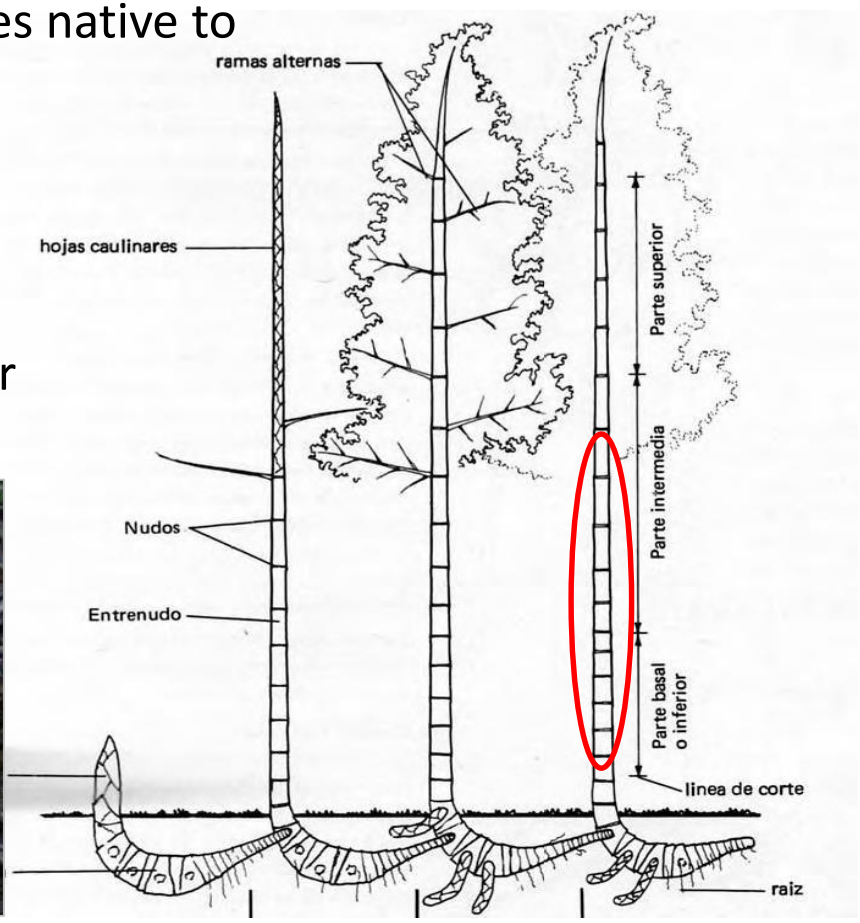
Bulk density = 650-800 kg/m^3
Bulk energy density = 12 - 19 GJ/m^3

Case study: Guadua *angustifolia*

- Woody bamboo species native to Latin America.
- Fast growing:

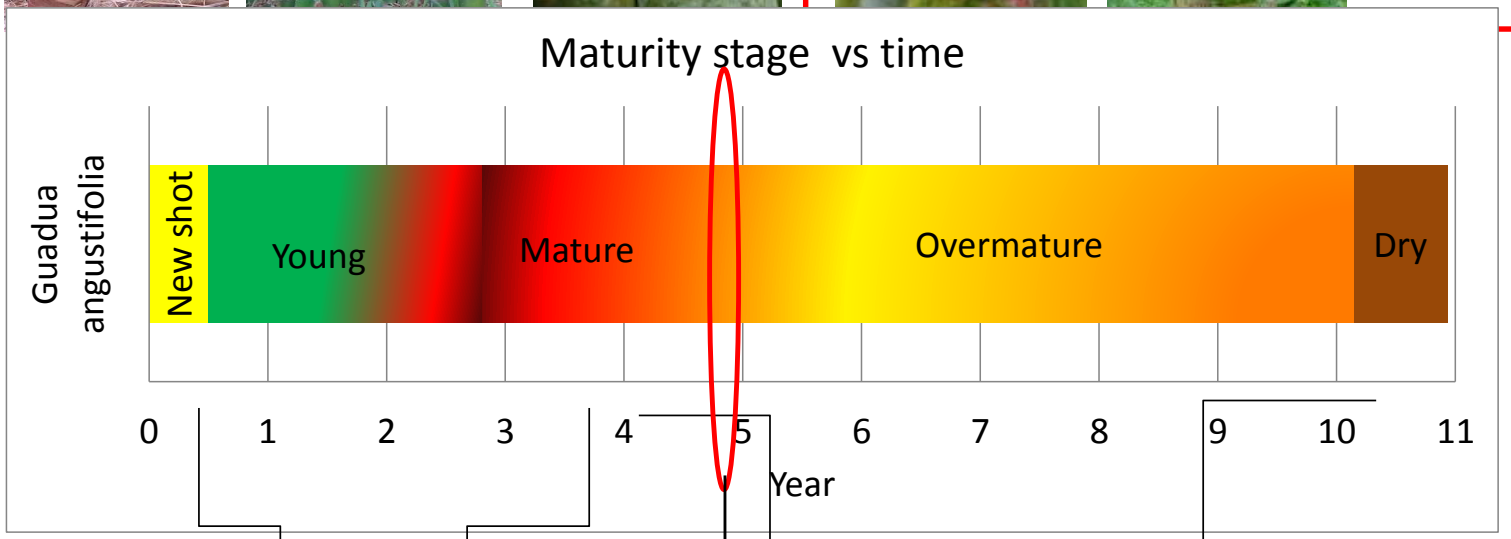
  30 m in 6 months

  20-40 Ton/ha-year



Guadua *a.* development stages

Residues



Major components

Celullose
Hemicellulose

Lignin

End Use

Biorefining

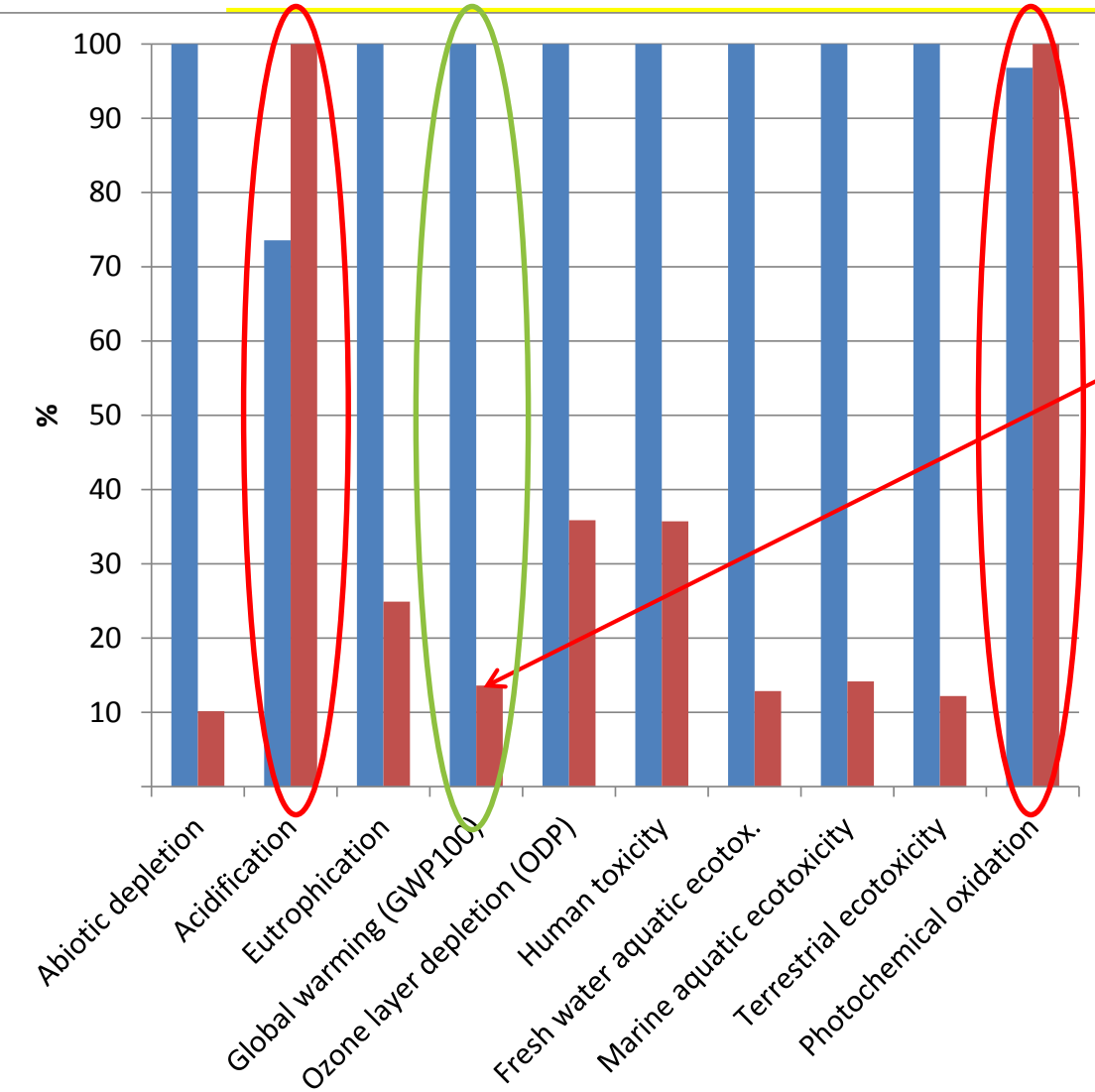
Construction

Fuel

Sustainability certification

Sustainability criteria included	FSC	NTA8080
Biodiversity	Yes	Yes
GHG	No	Yes
Environment	Yes	Yes
Social	Yes	Yes

1 MJ of Electricity: Coal vs. Bamboo



88 % GHG emission reduction

NTA8080 = 70%

Accounting methodology follows:

EC recommendations for solid biomass

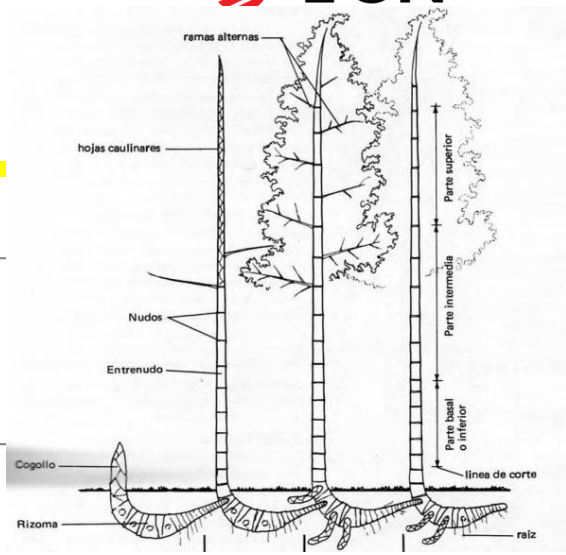
Default values/processes/references

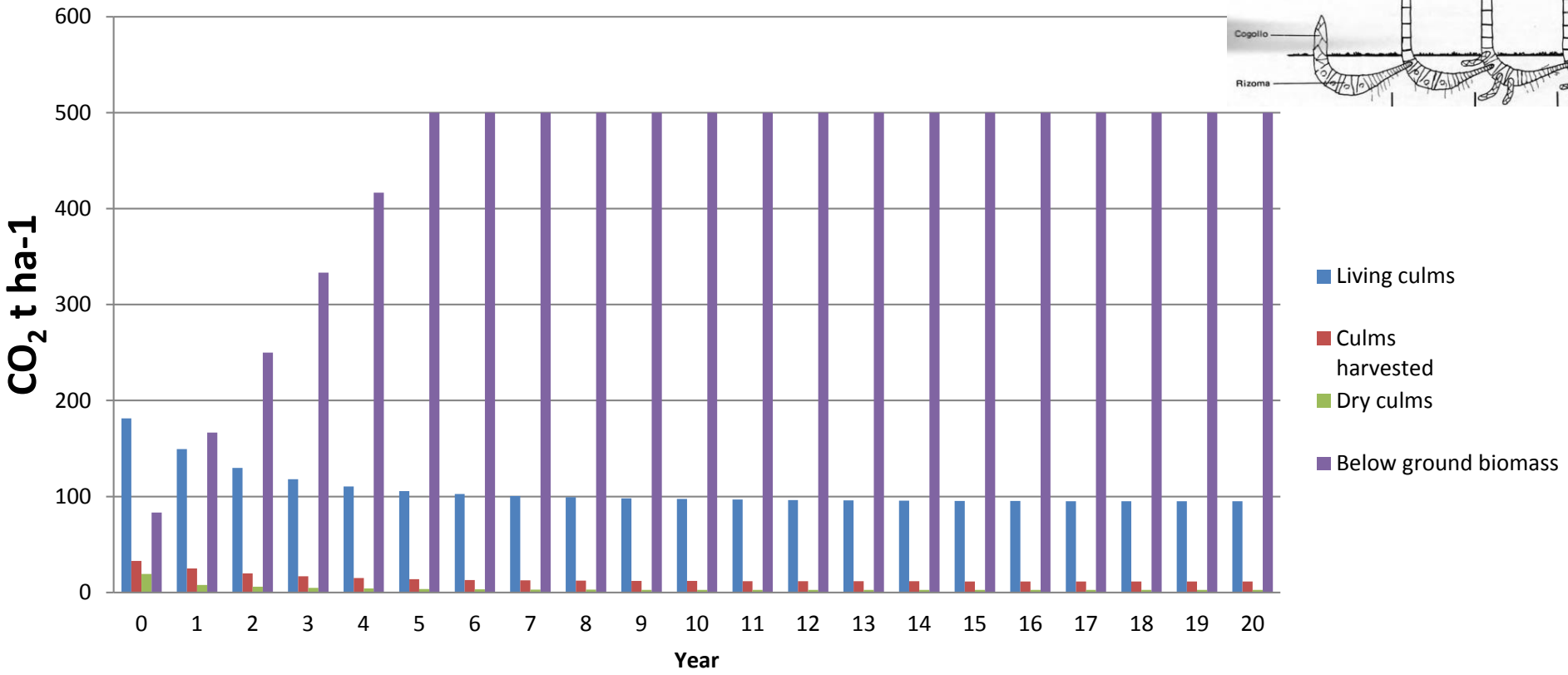
Carbon stock is not included

What if carbon stock is included?

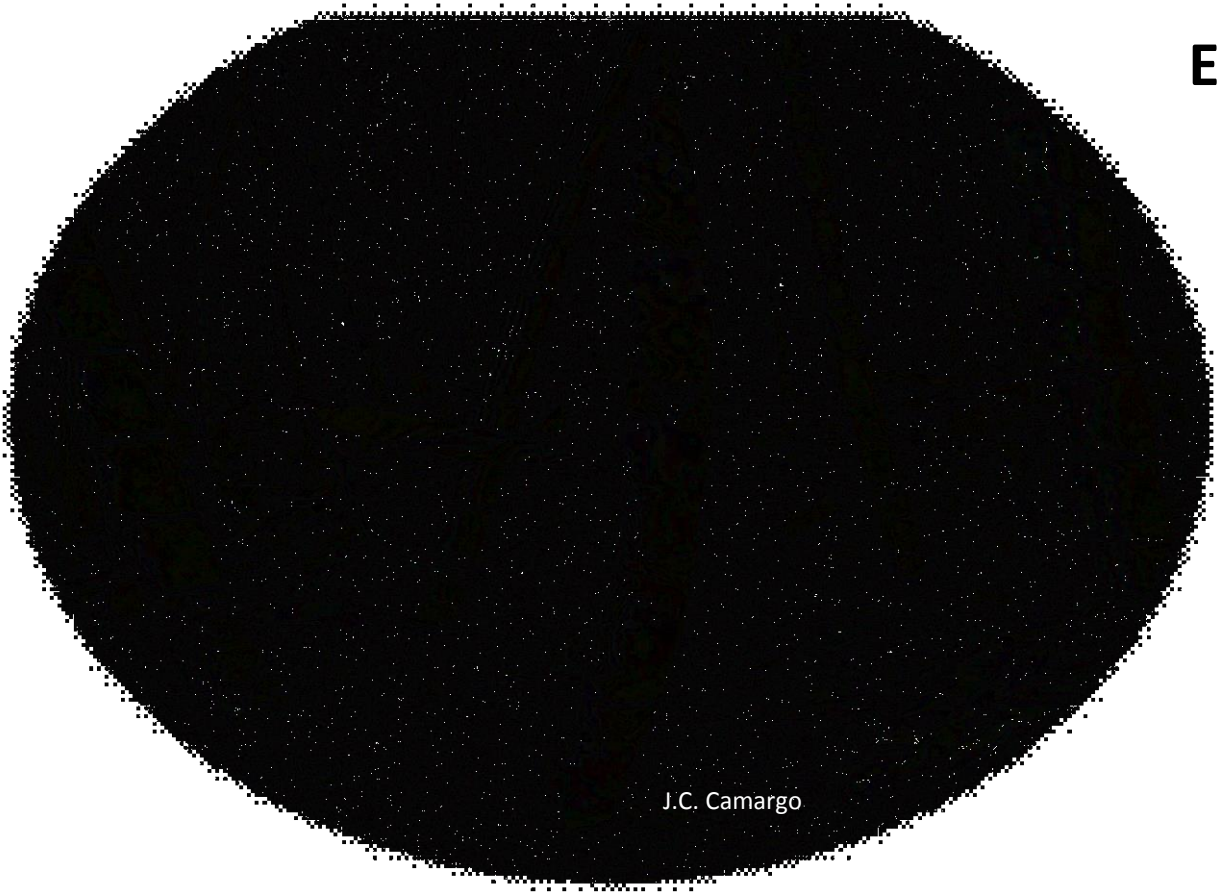
Living stands

Below ground biomas: (soil organic carbon, roots)





When carbon stock is included: CO_2 storage



Estimated GHG emissions:

Reduction: 300 % vs. 88%

Harmonize methodologies

Measure, monitor and demonstrate

Conclusions

- Bamboo has the potential to be a highly sustainable biomass source for the biobased economy➔ species, location and practices dependent.
  - Fuels
  - Chemicals
  - Materials
- Sustainability certification is possible
- Regulatory framework in producing countries
- Research and Development
  - New “traditional” biomass chain
  - Multidisciplinary approach

Thank you for your attention

This work forms part of the project: “Torrefied bamboo pellets for sustainable biomass import from Colombia”. Financial support by NL Agency under the subsidy scheme Sustainable Biomass Import. Partners in the project were: Imperial College of London (UK), Technological University of de Pereira (Co), Colombian Bamboo Society (Co).

NL Agency
Ministry of Economic Affairs

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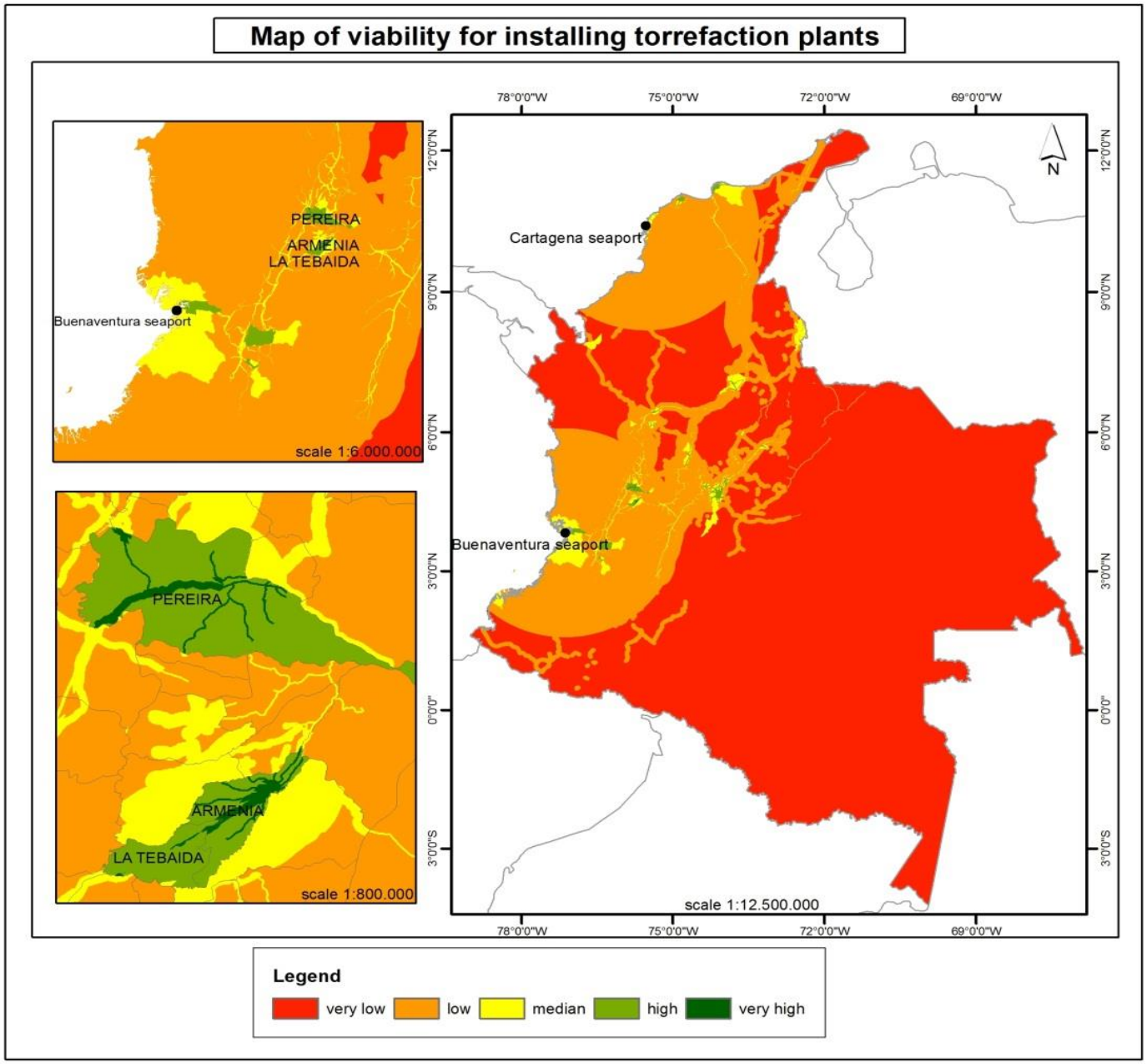


Fuente: Amezquita et al. 2011

DIFERENCS BETWEEN GUADUA/BAMBÚ VS. TREES

ECN

GUADUA/ BAMBOO

1. **It is** autoreproducible.
2. Culm or stalk is hollow, cylindrical & segmented
3. No bark or central heart. The hardest part is the area of the periphery and is in the outer.
4. No cambium tissue and does not increase culm in diameter with age.

WOOD / TREE

1. **It is Not** auto-reproducible.
2. Solid stalk and not segmented.
3. Has bark and aged cells form the hardened heart of the tree which is in the center.
4. Has cambium tissue and stalk increases in diameter with age.

SOCIEDAD COLOMBIANA DEL BAMBU

Residues vs Bioenergy crop

	Residues from forest	Residues from plantations	Bioenergy crop	Comments
Yield per ha	+	++	+++	Forest explotaition needs permit
Current potential	++	+	--	Existing area covered/ Species
Future Potential	++	++	+++	Suitable area
Cost	++	++	+	Main production/management cost are allocated to main product
Small holders	++	+	+	Nucleos forestales
GHG emissions reduction	+	+	+++	Use of residues account for emissions from the collection point➔Does not include carbon stock

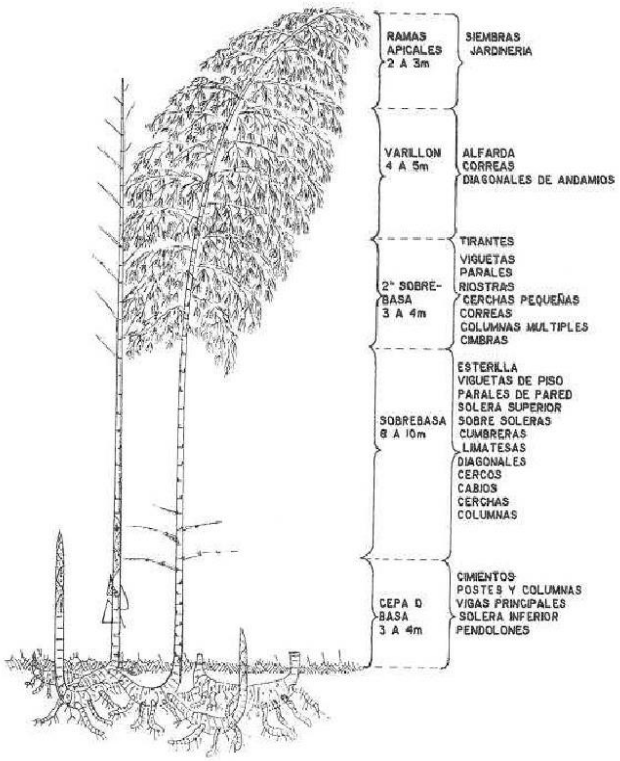
Alternative Species Selection

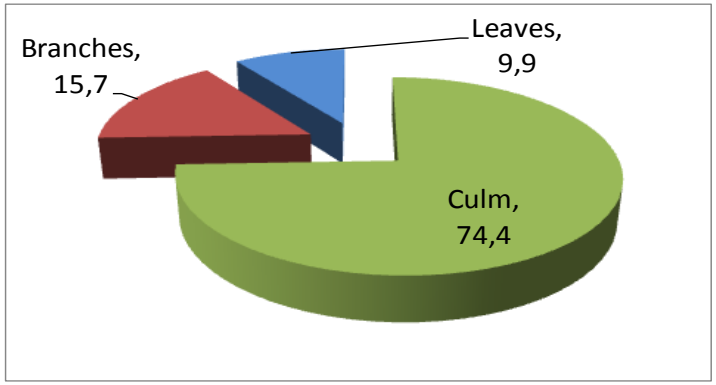
1. *Guadua angustifolia* Kunth (500 - 1.600 masl)
2. *Guadua amplexifolia* Presl. (0 - 800 masl)
3. *Chusquea subulata* Clark (2.200 – 2.800 masl)
4. *Bambusa vulgaris var. vulgaris* (0 – 1.500 masl)
5. *Dendrocalamus strictus* (0 - 800 masl)

Selection Criteria
a) Culm size.
b) Productivity
c) Climate and soil conditions

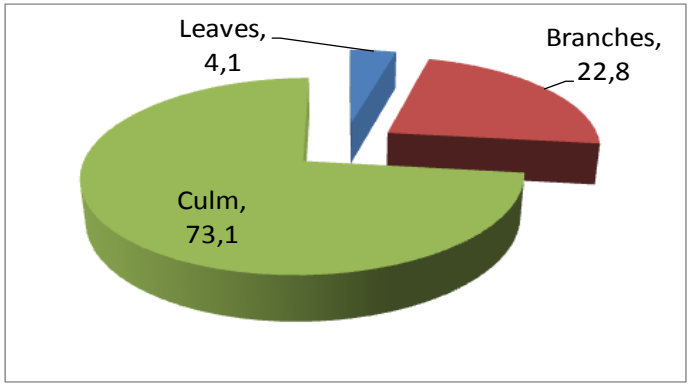
(Londono et al 2011)

Above ground biomass

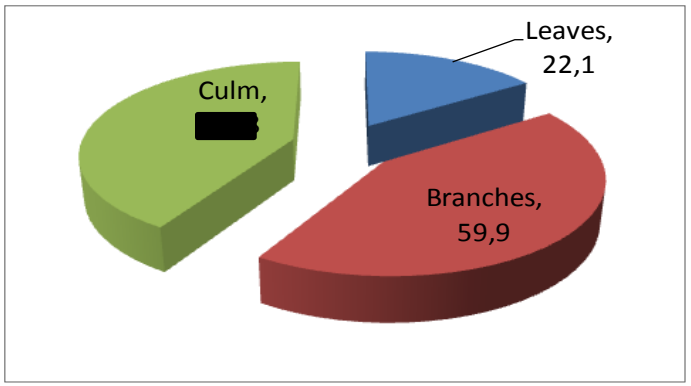




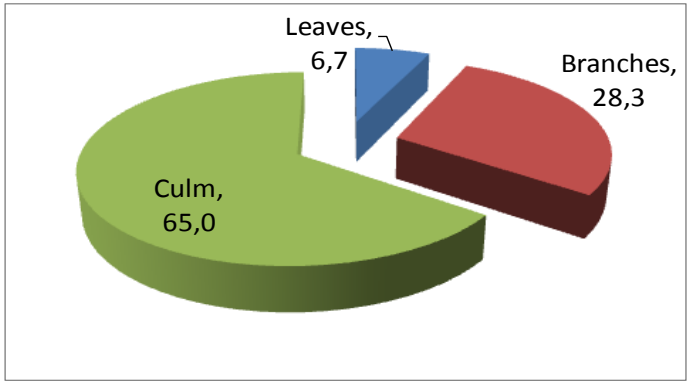
***G. angustifolia*[1]**



***B. vulgaris*[1]**



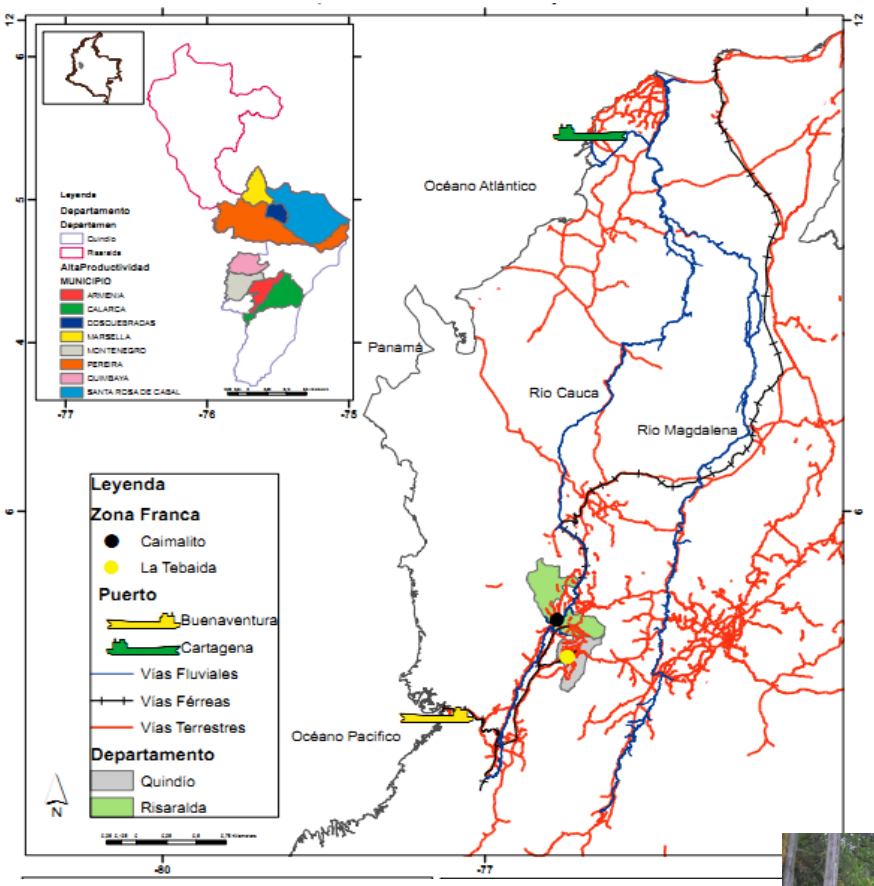
***G. amplexifolia*[1]**



***D. strictus*[1]**

(Camargo et al 2011)

Logistics



Bamboo density is superior to other biomass

(600 kg/m³ vs. 200-300 kg/m³)➔Transport €/Ton

Options:

- **Flattened culms/chips/pellets**
- **Shipping**
- **Local pre-treatment**

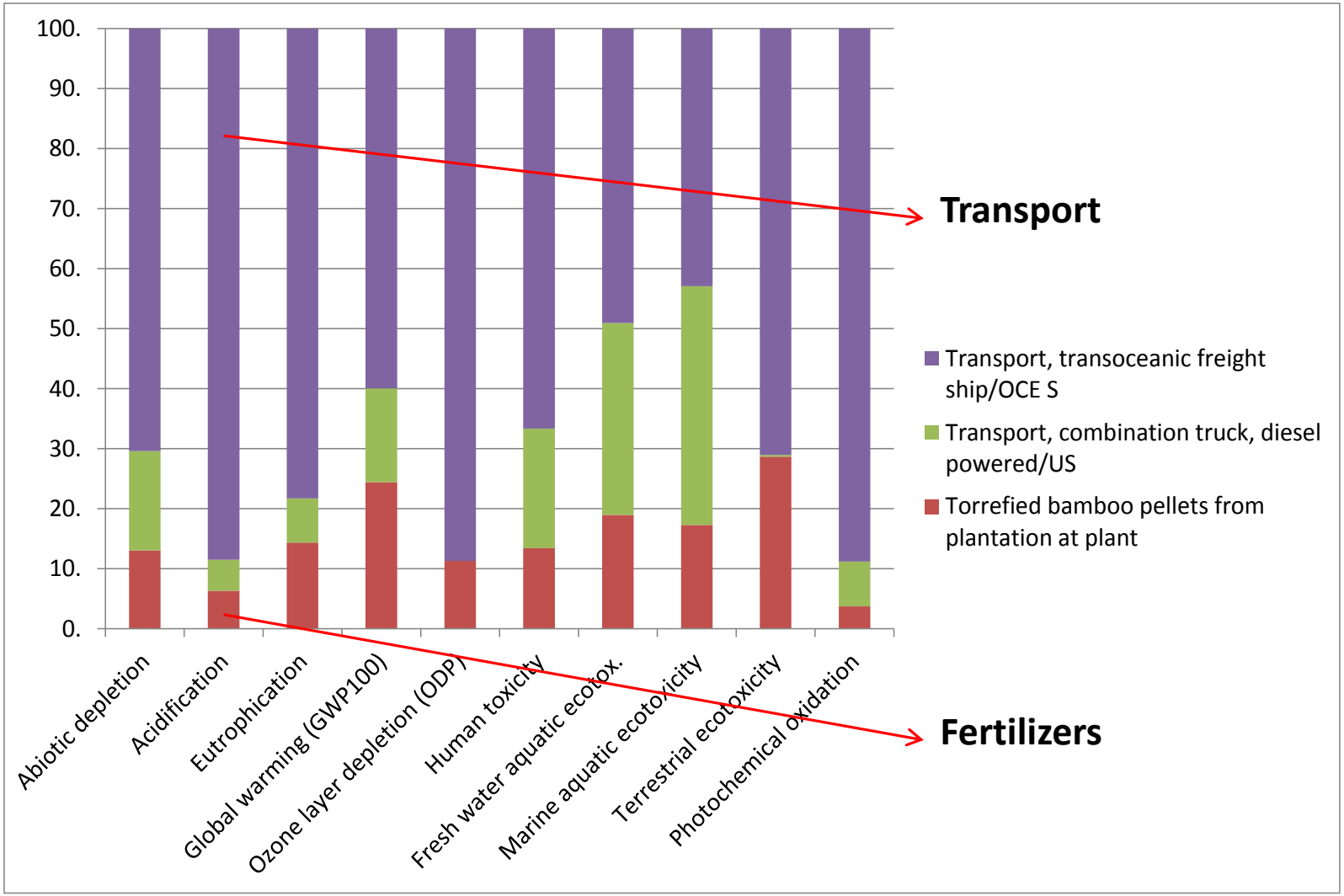
Life Cycle Assessment

SimaPro Software + CML method (Centrum voor Milieukunde Leiden (CML)

Impact category	Definition	Unit
Abiotic depletion	Depletion of non-living natural resources, including energy resources	kg Sb[1] eq.
Global warming	**Contribution of a substance to the greenhouse effect**	**kg CO_2 eq.**
Ozone layer depletion	Thinning of the stratospheric ozone layer as a result of anthropogenic emissions	kg CFC[2]-11 eq.
Human toxicity	Impacts of toxic substances present in the environment on human health	kg 1,4-DCB[3] eq.
Fresh water aquatic ecotoxicity	Impacts of toxic substances on freshwater aquatic ecosystems	kg 1,4-DCB eq.
Marine aquatic ecotoxicity	Impacts of toxic substances on marine aquatic ecosystems	kg 1,4-DCB eq.
Terrestrial ecotoxicity	Impacts of toxic substances on terrestrial ecosystems	kg 1,4-DCB eq.
Photochemical oxidation	Capacity of volatile organic compounds and carbon monoxide to produce photo-oxidants such as ozone	kg C_2H_4 eq.
Acidification	Impacts of acidifying pollutants (mainly SO_2, NO_x and NH_x), through emissions to the air, on the natural and man-made environment, human health and natural resources	kg SO_2 eq.
Eutrophication	Impacts of eutrofying substances (nutrients), through emissions to air, water and soil, on the natural and man-made environment, and natural resources	kg PO_4^{3-} eq.

[1] Sb = antimony [2] CFC = Chlorofluorocarbons [3] DCB=Dichlorobenzene

Impact distribution



Biomass production: FSC Certification

- **FSC standard for Guadua**
  - **Colombian national interpretation for guadua bamboo forest**
  - **1st in the world➔ Now used in Asia**
- **Some forest of “Guadua *angustifolia* Kunth” are FSC certified ➔ Small holders**
- **Access to international market.**

~~Torrefaction~~ Torwash

Tested biomass: bamboo

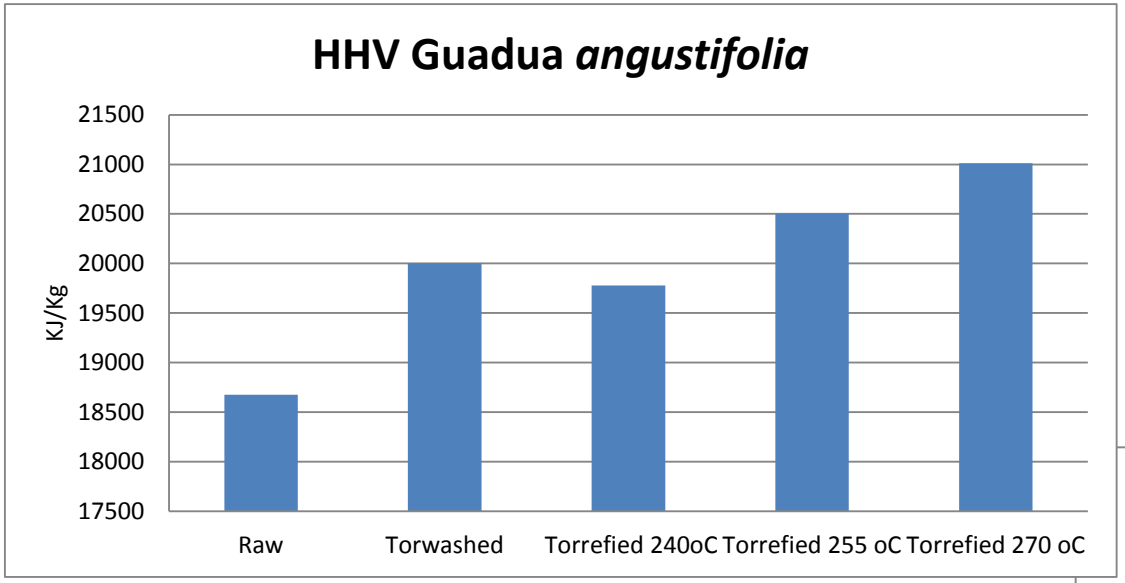
- TORWASH

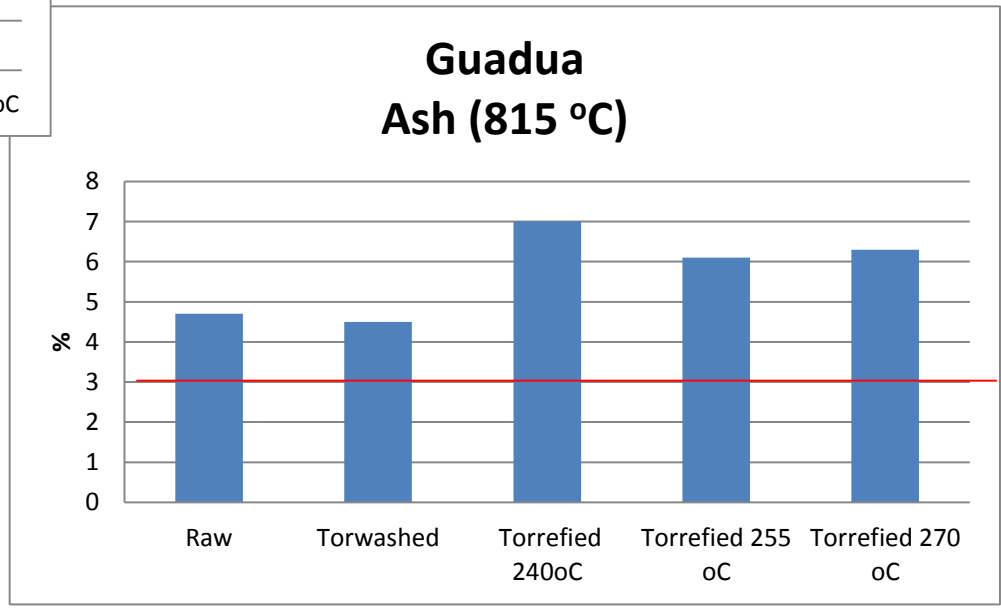
  Combining torrefaction with a washing step in order to recover certain minerals from biomass in order to use it as a non-fossil fertiliser

  (Hydrothemal Torrefaction)

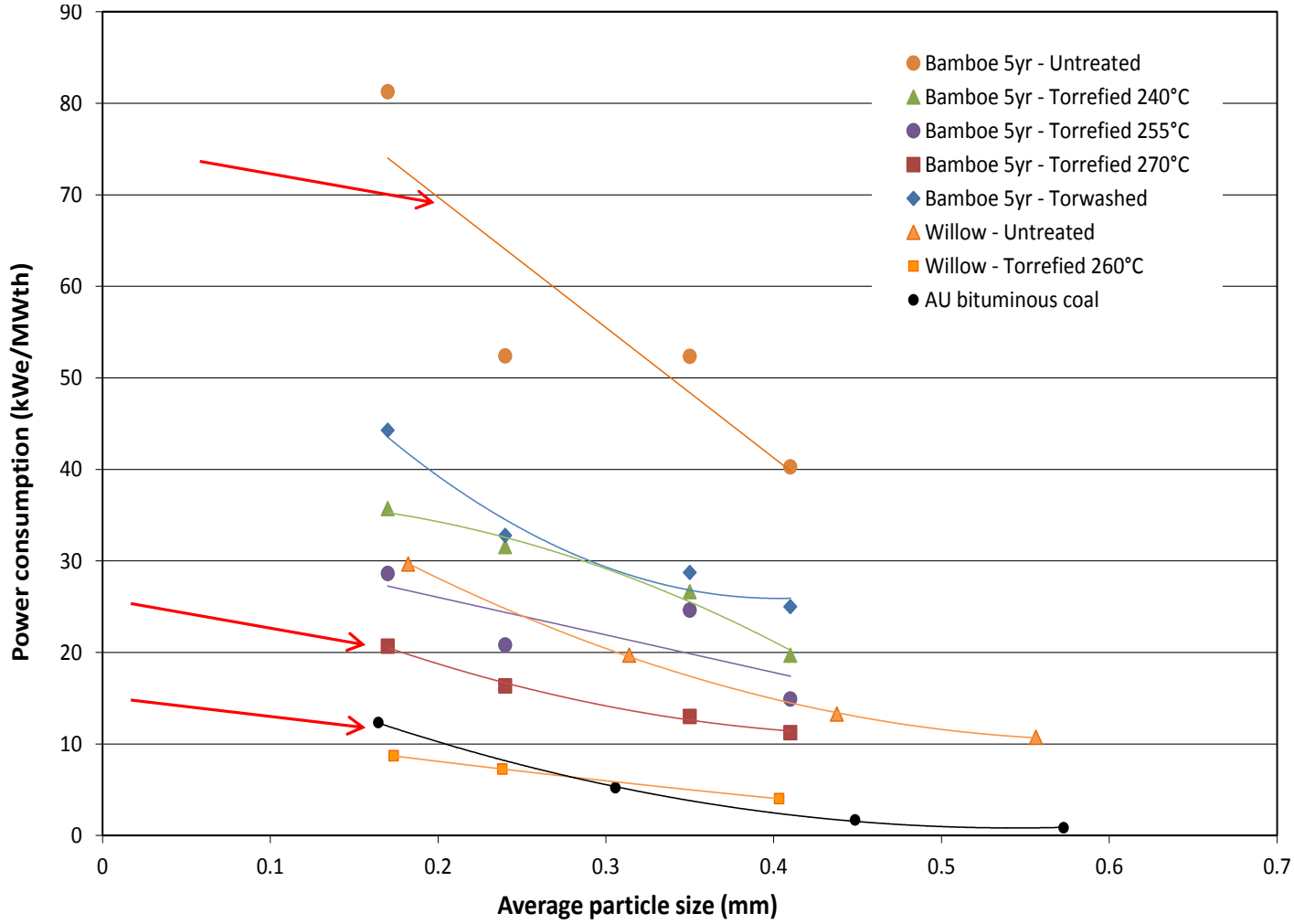
Proximate &ultimate (% mass, dry fuel)			
	Raw	Torwashed (wet torrefaction)	
ash @ 815°C	6,3	4,5	
Ash composition (mg/kg fuel, dry fuel)			
K	23029	510	→ ***-98%***
Cl	568	120	→ ***-79%***

Fuel Analyses



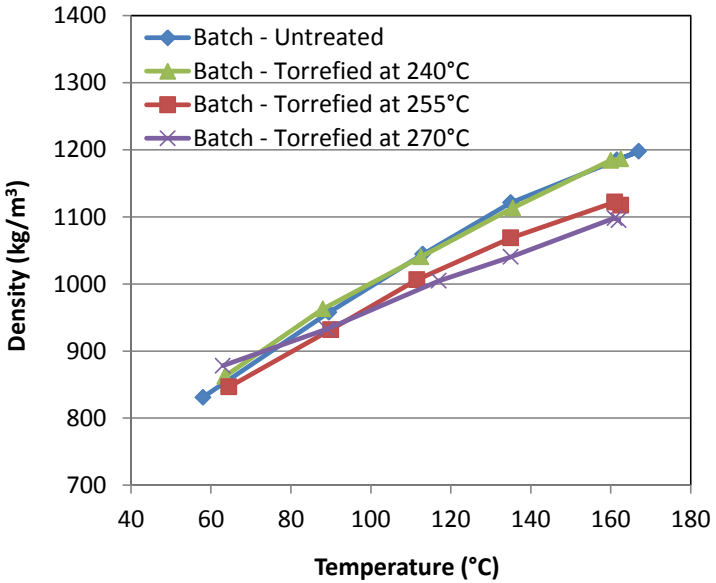


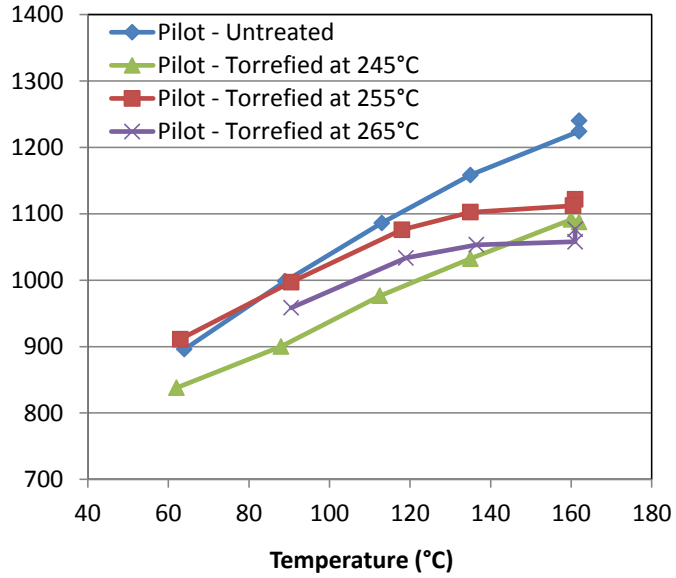
Grindability



Janssen, A.

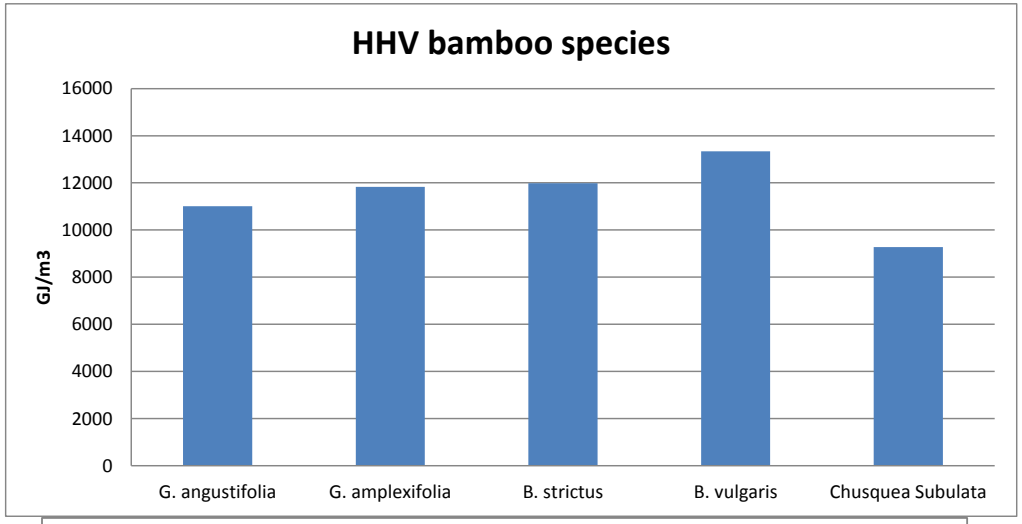
Bamboo Pellets

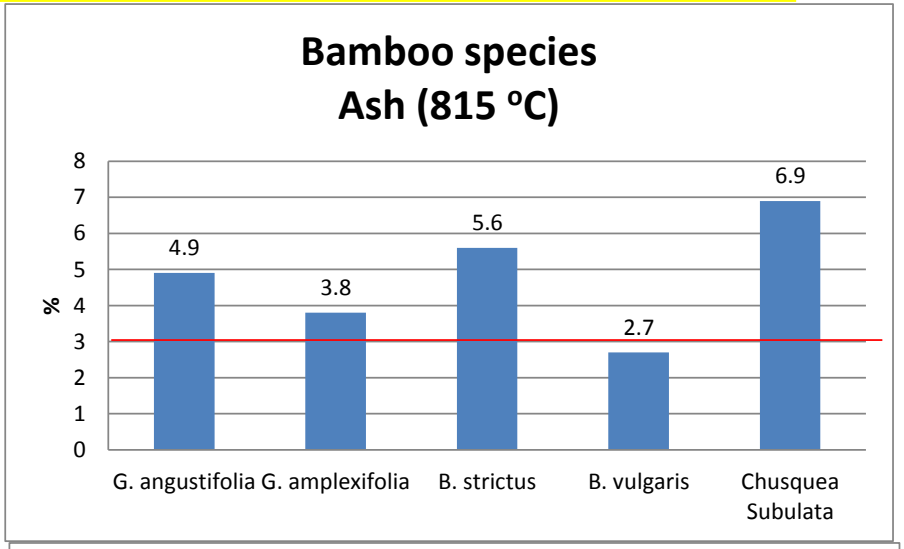


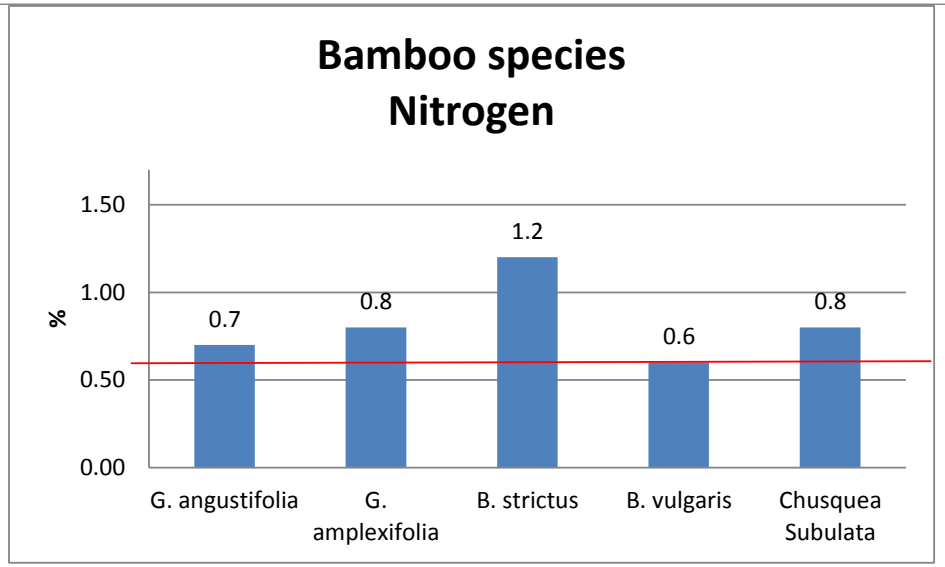


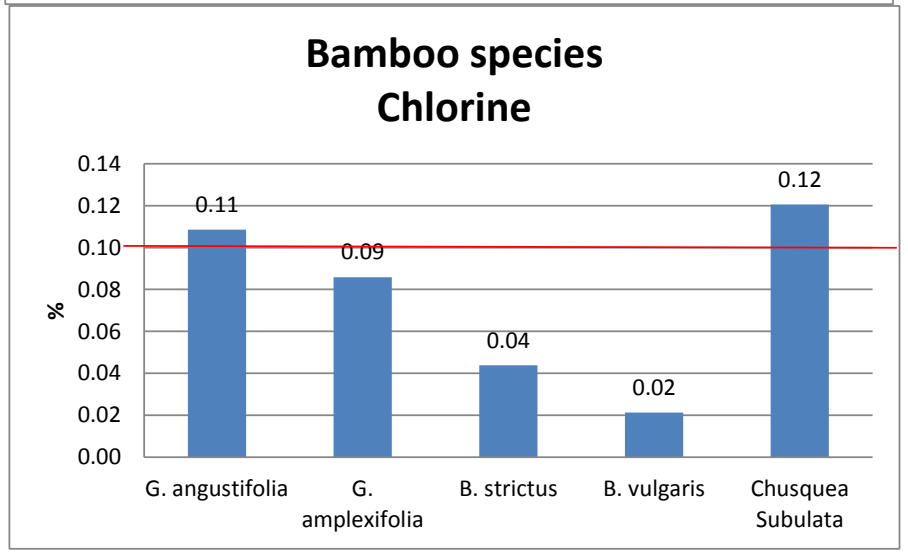
Very rough estimates of the achieved densities were ± 1250 kg/m^3 (pellet) and ± 610 kg/m^3 (bulk).

Alternative potential species



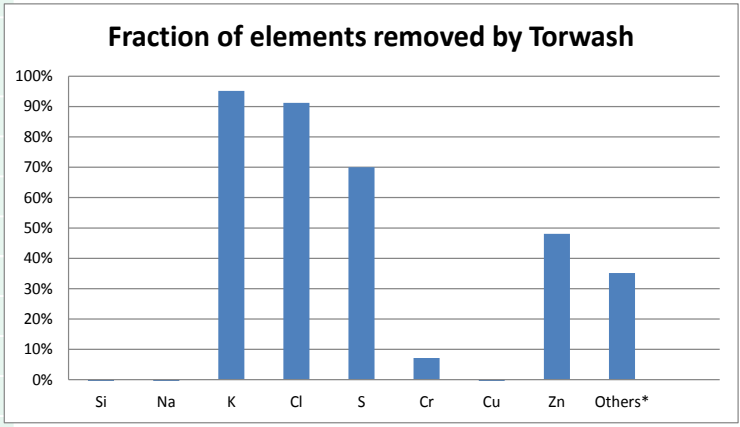




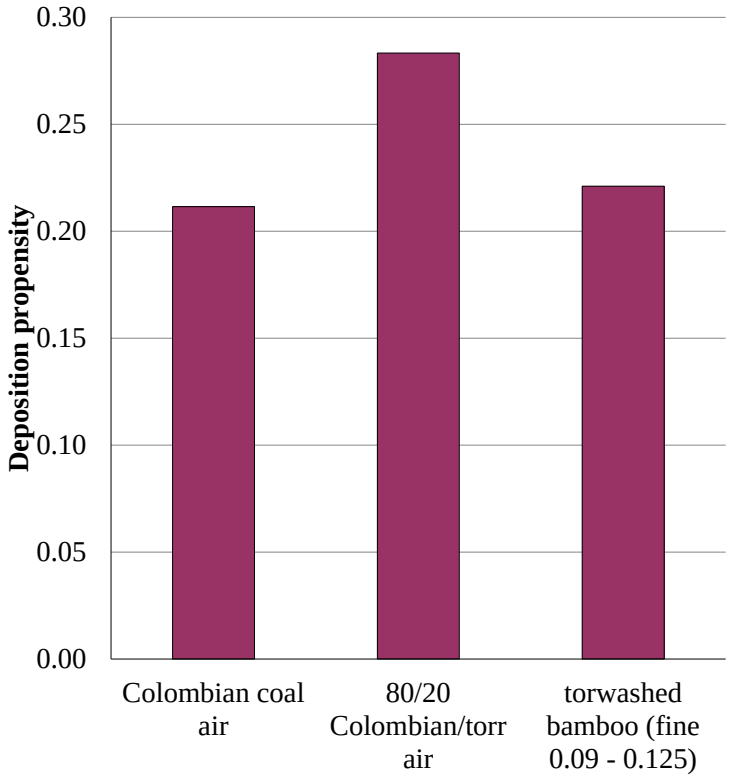


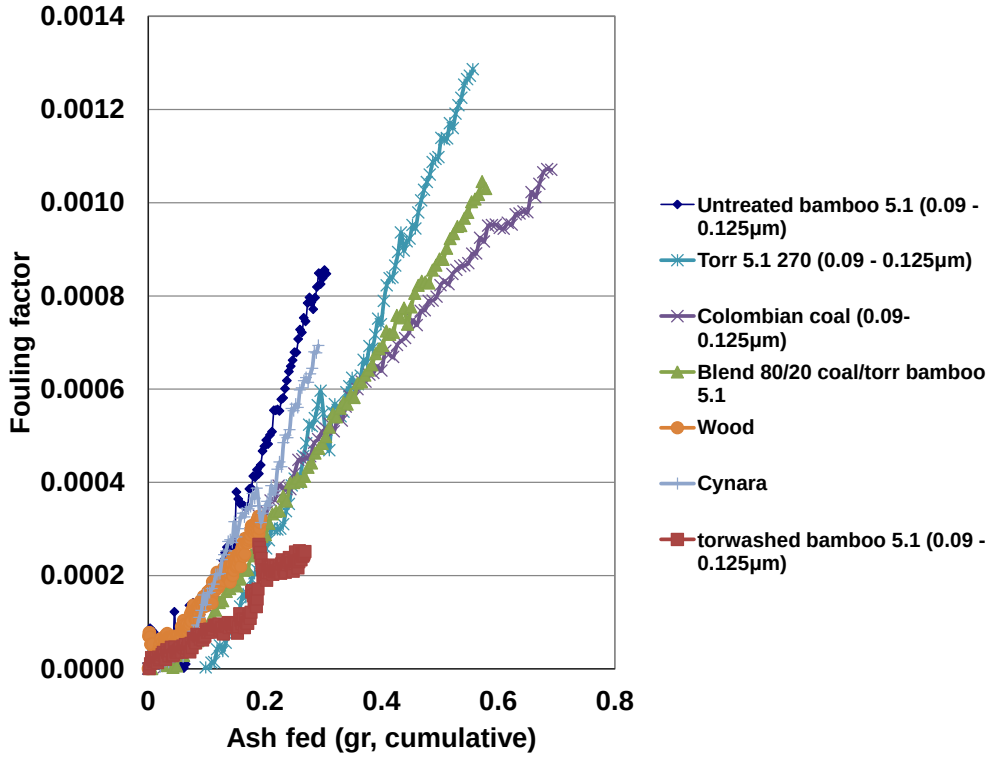
Fuel properties

Fuel	Russian Coal	Wood	Guadua angustifolia
Moisture	10.4	7.1	16.4
Proximate analysis (% mass, dry fuel basis)			
Ash @ 815°C	8	1.44	4.7
Volatile matter	32	80	77
HHV (KJ/kg)	27800	20093	18676
Ultimate analysis (% mass, dry fuel basis)			
C	68	50.25	46.5
H	4	6.13	5.9
N	0.87	0.37	0.33
S	0.35	0.026	0.09
O by diff.	11.6	44.2	43
Ashcomposition (mg/kg fuel, dry basis)			
Na (± 7)	405	191	3.4
Si (± 90)	34841	1331	13492
S	3500	260	868
K (± 20)	2390	984	10539
Cl (± 20)	100	253	1362



Combustion tests





Fryda et al

- **Similar to wood**

~~Torrefaction~~ Torwash

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ECN 50 kg/h torrefaction pilot plant
(Since February 2008)

Torrefaction tests at ECN

feeding


torrefaction


pelletization


1-10 tons of test batches


untreated Bamboo - Guadua

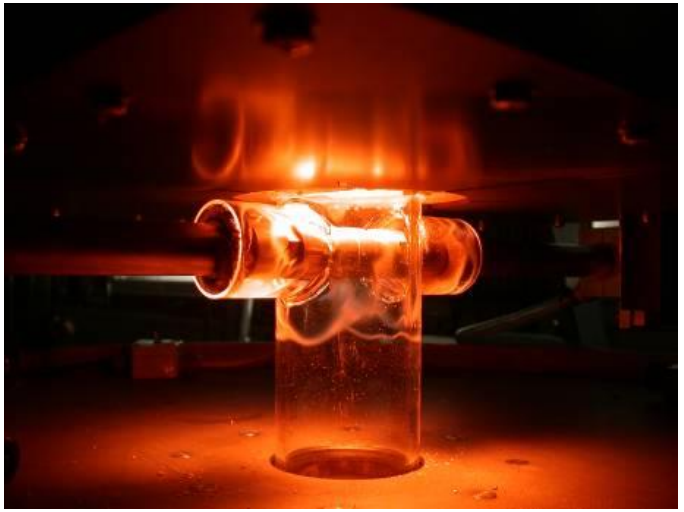

Bamboo - Guadua treated @ 245°C


Bamboo - Guadua treated @ 255°C


Bamboo - Guadua treated @ 265°C

Combustion

- Combustion simulator (LCS)
  - Combustion characteristics
  - Slagging and fouling
  - Emissions (NOx, SOx, Dioxins)



- Fuel and Ash characterisation

  - **Main result: Similar to wood**